SOME NEW ANATOMICAL CHARACTERS FOR CERTAIN GRAMINEÆ

A dissertation presented to the Faculty of Philosophy of the Catholic University of America, for the degree Doctor of Philosophy

By HERMAN THEODOR HOLM,

Candidatus Philosophiæ, Copenhagen, June, 1902

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Some important new facts to be brought out in this study require the brief statement of a few fundamentals of plant-anatomy and especially the matter of the structure of what has been called the parenchyma-sheath. — This sheath, which consists of a single layer of relatively short cells, surrounds the mestome-bundles of the leaves and, partly also, of the stem of the majority of monocotyledonous plants: *Gramineae*, *Cyperaceae*, *Juncaceae*, etc., and has also been found in nearly all the orders of the *Dicotyledones*. It is generally thin-walled and contains chlorophyll to the same extent as the surrounding mesophyll or it may appear as totally destitute of chlorophyll, and with some of the cells thick-walled, especially on the leptome-side, when in contact with supporting bundles of stereome. Such variation in the relative thickness of the cell-walls and in the cell-content may be seen in the same leaf by comparing mestome-bundles of different size and development. But one character is constant, namely, that the parenchyma-sheath borders directly on the mesophyll or on the cortical parenchyma, whether this is differentiated into palisades or not, thus connecting the leptome and hadrome with the assimilating tissue.

The literature of this subject, the structure of the parenchyma-sheath, is extensive and well known. But besides the ordinary parenchyma-sheath, as we may call it, some others occur inside this, namely, the mestome-sheath, described by Schwendener*) as characteristic of all the *Cyperaceae* and a number of *Gramineae* and *Juncaceae*, and finally the inner chlorophyll-bearing sheath which Haberlandt**) detected in certain species of *Cyperus*. Of these the mestome-sheath is generally prominently thick-walled and thereby easily distinguished from the surrounding parenchyma-sheath, although some cases are known where the mestome-parenchyma itself attains a development like that of a true mestome-sheath (l. c.). In such cases the treatment of the sections with concentrated sulphuric acid and a very careful comparison of the large and small mestome-bundles is necessary for deciding whether such sheaths really represent a mestome-sheath or only a layer of mestome-parenchyma. Haberlandt's chlorophyll-bearing sheath is a third form of sheath, which so far has only been observed in some genera and species of *Cyperaceae* in accordance with the obser-

*) Schwendener, S., Die Mestomscheiden der *Gramineen*-Blätter. (Sitzungsber. d. K. Academie Berlin. 1890. p. 405.)

**) Haberlandt, G., Physiologische Pflanzenanatomie. Leipzig, 1884. p. 174. Fig. 61.

vations of Rikli *) and the writer.**) This inner chlorophyll-bearing sheath is always located inside the mestome-sheath, whether the outermost parenchyma-sheath is present or not, and its green cell-content and mostly thin cell-walls make it readily distinguishable from any form of true mestome-sheaths.

Over and above these distinct sheaths thus named and briefly characterized, and which are more or less familiarly known to plant-anatomists, there exists, as the researches, the results of which are herein given to the public, prove, that which may be called a second or a double parenchyma-sheath.

While engaged in an anatomical study of a collection of plants made by the writer during the summers of 1896 and 1899 in Colorado, we noticed among the *Gramineae* from the plains, that *Aristida fasciculata* exhibited distinctly a double parenchyma-sheath. Being unable to find any record of this sheath, we submitted our observations to Professor Schwendener, who courteously informed us, that in spite of the large number of *Gramineae*, which he had examined, he had never observed any instance of such a structure. We did not, however, deem it advisable to publish our observations upon this individual instance, but thought that the same structural peculiarity might perhaps be shared by some of the other *Gramineae* from the plains or at least by other members of the genus. Therefore we have extended our research to as many species of *Aristida* as were available, and we have not omitted to consider allied genera, besides a number of other *Gramineae*, which to a more or less extent, are associated with the various species of *Aristida*: occupying the same soil and living under the same climatological conditions. The final result of our investigation is, however, that the structural peculiarity which we observed in *Aristida fasciculata* and which consists of the presence of a double parenchyma-sheath around the mestome-bundles is only possessed by certain species of this genus, not by all, and not by any of the other genera of grasses examined.

Characteristics of the double parenchyma-sheath.

In a transverse section of the leaf of the grass above named the mestome-bundles are seen to be surrounded by one or, sometimes, two layers of palisades, arranged radially around them. These palisades border inwards on a closed sheath of

*) Rikli, M., Beiträge zur vergleichenden Anatomie der *Cyperaceen* mit besonderer Berücksichtigung der inneren Parenchymscheide. [Inaug-Dissertation.] Berlin, 1895.

**) Holm, Theo., The genus *Lipocarpha* R. Br. (American Journ. of Sci., VII. 1899. p. 177) and *Fimbristylis* Vahl: an anatomical treatise of North American species. (Ibidem. VII. p. 435.)

thin-walled cells filled with chlorophyll. This encloses another sheath of larger cells, with slightly thickened walls and with the same contents as the outer one. Inside these sheaths are the leptome and hadrome of the same structure and disposition characteristic of the *Gramineae* in general. The mestome-bundles are, thus, surrounded by two very distinct sheaths, the cells of which are round in outline as seen in transverse sections, and they both contain chlorophyll, which as to color and relative size of grains, does not differ from that contained in the palisades. Viewed in longitudinal section both sheaths appear to be parenchymatic, somewhat stretched, but with almost horizontal cross-walls. In this particular the inner sheath departs from the structure characteristic of a mestome-sheath, as this term has been applied by Prof. Schwendener to certain internal sheaths, which occur in a number of *Gramineae*. Moreover the testing with concentrated sulphuric acid did not give the result, usually obtained in cases where a mestome-sheath is developed. While thus the mestome-bundles of *Aristida fasciculata* lack a mestome-sheath, there exist in the larger of these some thick-walled cells on the leptome-side in the shape of an arch, besides a single layer between the leptome and hadrome, but these cells proved to be thick-walled mestome-parenchyma.

In comparing this leaf-structure with that of other genera of *Gramineae* we have failed to find a corresponding case where two parenchymatic and chlorophyll-bearing sheaths occur inside radially arranged palisades. The outer of these sheaths represents, no doubt, the ordinary parenchyma-sheath, which surrounds all the mestome-bundles in the *Gramineae*, and which lies close up to the adjoining palisades, whether a mestome-sheath is present or not; but in regard to the inner sheath of larger cells we can not at present designate this by any other name than "an inner parenchyma-sheath", though we prefer to speak of them both unitedly as "a double sheath."

It was, at first, our thought that the innermost of these sheaths might be morphologically analogous to the very similar one, which has been described by Haberlandt, Rikli and the writer as characteristic of no small number of *Cyperaceae*, but for reasons to be mentioned later, we have relinquished this idea.

Leaf-structure of *Aristida* in general.

Continuing our study of *A. fasciculata* we might mention the other tissues of the leaf, so as to give a more complete illustration of this peculiar structure, even if the leaf in other

respects shows many points of likeness to those of various other genera from arid regions such as have been figured and described by Volkens*) and Duval-Jouve.**) *Aristida fasciculata* is very common on the plains of Colorado, it is perennial and of a caespitose habit; the leaves are rigid, mostly erect, pale-green, conduplicate when dry and their upper face is deeply furrowed. The cuticle is smooth, but thick, and the epidermis is very thick-walled especially on the lower face where the thickening of the cell-walls is so prominent as to form longitudinal ridges outside the broad layers of the subepidermal stereome. Short papillae are rather scarce in this species, while numerous, unicellular and pointed hairs abound on the ridges of the upper face of the blade, where they cover the narrow furrows, in the bottom of which epidermis is developed as small bands of bulliform cells. The stomata are level with epidermis and are confined to the sides of the furrows. A water-storage tissue of a few layers of large, colorless cells is to be seen underneath the bulliform cells, from where it extends to the subepidermal stereome of the lower surface. The stereome is very thick-walled and accompanies the mestome-bundles as, in transverse sections, broad and flattened groups on both the leptome and the hadrome-side; an isolated, smaller group of the tissue is also observable on the leaf margin, besides, as stated above, there are layers of stereome underneath the water-storage-tissue between the ribs; it is not unusual to find almost the entire lower face of the leaf covered by one confluent mass of stereome. The mesophyll consists of palisades, which radiate towards the center of the mestome-bundles, and no mesophyll was observed in the furrows. — We have, already, described the sheaths, that are observable around each bundle, but we might state here, that both of these show the same tendency of becoming thick-walled when in contact with the supporting stereome as the ordinary parenchyma-sheath, a fact that is readily observable in the larger bundles. The mestome bundles are all located in the ribs, of which the median one is not larger, neither more projecting or thicker, than most of the others; in regard to the outline of the bundles, seen in transverse sections, this is mostly oval, very seldom orbicular.

The occurrence of the double parenchyma-sheath is not, however, restricted to the leaf, but is also noticeable in the culm, though with the following modification; it is only present on that part of the mestome-bundles, which is also surrounded by

*) Volkens, Georg, Die Flora der Aegyptisch-Arabischen Wüste. Berlin 1887.

**) Duval-Jouve, G., Histotaxie des feuilles de *Graminées*. (Annales d. sc. nat. Botanique. Séries VI. Vol. I. p. 294.)

the green cortex, palisades that are arranged in the same manner, as observed in the leaf. But where the mestome-bundles are directly surrounded by stereome, the sheaths are not developed.

The leaf structure of other species of *Aristida.**)

Aristida fasciculata belongs to the section *Chaetaria* of Bentham and Hooker, a genus with Beauvais and Nees, and since this section is exceedingly well represented in North America, we have also examined a number of other species to ascertain whether this structural peculiarity is a sectional or only a specific character; moreover we have compared the leaf structure of a few species of the same section, but from other parts of the world.

The following species of the section *Chaetaria* have been examined:

Aristida Adscensionis L. (Eastern India).
" *arizonica* Vas. (New Mexico: Santa Fé).
" *basiramea* Engelm. (*Arizona:* Sierra Tucson).
" *Behriana* F. v. Muell. (Australia).
" *bromoides* H. B. K. (Texas).
" *coerulescens* Desf. (Spain: Malaga).
" *delicatula* Hochst. (Abyssinia).
" *depressa* Retz. (East India).
" *dispersa* Trin. et Rupr. (New Mexico: Organ Mts.).
" *fasciculata* Torr. (Colorado: Denver).

Aristida gracilis Ell. (D. C. Brookland).
" *Havardii* Vas. (Texas: Presidio Co.).
" *Humboldtiana* Trin. (New Mexico: Organ Mt.).
" *Hystrix* L. (East India).
" *intermedia* Scribn. (Missouri: Biloxi).
" *Kotschyi* Hochst. (Nubia).
" *lanata* Poir. (Mo: dry Pine-barrens).
" *Meccana* Hochst. (Nubia).
" *murina* Cavan. (Uruguay: Montevideo).
" *Nealleyi* Vas. (Texas: Presidio Co.).
" *oligantha* Michx. (D. C.: Brookland).
" *palustris* Vas. (Mo.: Biloxi.).
" *purpurascens* Poir. (D. C. Brookland).
" *purpurea* Nutt. (Ariz.: Tucson).
" *ramosissima* Engelm. (Mo.: San François Co.).
" *Reverchonis* Vas. (Texas: Presidio Co.)
" *scabra* Kunth (*patula* Chapm.) (Florida: Titusville).

*) In securing this extensive material of *Aristida* the writer is greatly indebted to Professor Arechavaleta, Messrs. Ths. H. Kearney and F. Lamson-Scribner for specimens of several rare species, which have been of great importance in the present study.

Aristida simpliciflora Chapm. (Florida: Apalachichola).
" *spiciformis* Ell. (Florida : Tampa).
" *stricta* Michx. (Florida : Jacksonville).
" *vagans* Cavan. (Australia).
" *virgata* Chapm. (Florida).

The majority of these species are inhabitants of dry, sandy or clayish soil on plains and prairies, while some occur also on mountain slopes; only a very few: *A. palustris* and *spiciformis* were collected in moist ground in pine-barrens. However if we compare the leaf-structure of these species with that of *A. fasciculata*, it is readily noticed that the arrangement of the tissues is exactly the same in all these species; moreover the blade exhibits the same furrowed upper surface and is more or less conduplicate when dry, with power to open, when the atmosphere becomes charged with moisture. — None have broad leaves, and in no instance is the midrib any more prominent than most of the others, neither on the upper or on the lower face, there being no stereome so prominently developed beneath the midrib so as to form a keel and no larger group of bulliform cells above this to distinguish it from any of the others. It would not, however, be difficult to draw up a list of anatomical characters, by which many of these species might be recognized, but as the object of the present study is not to establish an anatomical characterization of the species, we will confine ourselves to a mere general consideration of the various modifications, which the leaves exhibit.

Beginning with the epidermis, we have mentioned the development of long hairs on the upper surface of *A. fasciculata*, and a similar covering of the blade is also observable in a number of species, while in others the epidermal projections consist merely of short papillae, pointed or nearly obtuse. But there is no evidence this varied covering with hairs or papillae is produced by the nature of the surroundings, hence constituting an epharmonic character, for we find the long hairs developed on the leaves of *A. spiciformis*, and the short ones on those of *A. palustris*, both which species, as stated above, are inhabitants of moist localities in the southern States. And among species from plains and prairies the same variation exists, some having hairy leaves, and others merely scabrous, although the species may grow almost side by side. The bulliform cells show the same location seen in *A. fasciculata*, but they are not uniformly developed in all the species. They are often very small, especially in leaves that are deeply furrowed, while they increase in size when the furrows are shallow. They are for instance relatively large in *A. Reverchonis*, *A. mexicana* and *A. purpurascens*, but very small in *A. oligantha* and

several others. — In some species where the furrows are both deep and narrow, the bulliform cells are seen to be relatively well-developed, for instance in *A. palustris* and *A. spiciformis*. The colorless tissue is invariably located between the ribs, but shows very little modification in number of layers and rows of cells.

As to the stereome, which is relatively well represented in *Aristida*, we find this to be uniformly distributed in these species, accompanying the mestome-bundles, and it also occurs underneath the water-storage tissue and on the margins of the blade. It may be very heavily thickened in some species, much less so in others, although from the same localities. In *A. spiciformis* for example the leaves are well supported in this respect, the stereome being extremely thick-walled and forming large groups of several layers, while the very opposite is to be seen in *A. palustris*. — The mesophyll, on the other hand, appears unvarying in all these species, and we have not noticed a single case in which the cells of this tissue were not differentiated into palisades, showing the same arrangement, as observed in *A. fasciculata*. — The mestome-bundles show but few modifiations, and these as to the relative thickness of the cell-walls of the inner sheath, which in some species are distinctly thicker than in those of the outer sheath. The cross-section of the mestome-bundles varies from orbicular to oval, both forms being most frequently observed in the same leaf, while it is rare to find the bundles of the orbicular type alone.

While thus the principal tissues in the leaves of *Aristida* of this section (*Chaetaria*) exhibit a very uniform structure, we noticed some deviation as to cell-content of the double parenchyma-sheath, which is not without interest. It is not uncommonly the case that the coloration of the chlorophyll, contained in these two sheaths, is somewhat different from that of the palisades, it being mostly of a deeper, bluish-green, besides that the chlorophyll is not always visible as grains in the inner sheath as in the palisades and in the outer sheath, but very often it appears as an amorphous cell-content. In *A. vagans*, for instance, the color of the chlorophyll in the inner sheath is deeply bluish-green, while that in the outer is of the same lighter green shade as that in the palisades. In *A. meccana* the cell-content of both sheaths is not only of the same deep bluish-green, but also differentiated into very distinct grains, somewhat larger than those contained in the palisades. When treated with iodine the cell-content of both sheaths becomes almost black like that of the palisades, the reaction thus being identically the same. In other species we observed the color of the cell-content in the sheaths to be much less marked when compared with that of the palisades, for instance in *A. pur-*

purascens, where the sheaths and palisades possessed chlorophyll of exactly the same shade, and a similar uniformity in color was also observed in some other species: *A. desmantha*, *A. Reverchonis*, etc. We have noticed this difference in color and consistency of the cell-content of the sheaths so often, that we are almost inclined to think that the variation may possibly depend upon the age of the leaf, rather than characteristic of certain species. It must also be remembered that the material, which we have studied, was in many cases not fresh, but had been dried or preserved in alcohol for several years.

In *A. dichotoma* Michx., the only representative of Beauvais' "*Curtopogon*," the structure agrees in all respects with that of the species of the section *Chaetaria*, described above. The bulliform cells are large, and the mestome-bundles are constantly small and orbicular in outline; the inner sheath is a little thick-walled in contrast to the outer one, and the color of the chlorophyll was observed to be deep bluish-green in both. A similar structure occurs in the two species of "*Streptachne*:" *A. divergens* Vas. and *A. Schiedeana* Trin., which are, thus, inseparable from *Chaetaria* anatomically; but while the cell-walls of both sheaths are very thin in the latter species, those of the inner one are quite thick in *A. divergens*, and the cells of this contain no chlorophyll.

Aristida californica Thurb., *A. desmantha* Trin. and *A. tuberculosa* Nutt., all indigenous to North America, belong to the group forming Beauvais' genus "*Arthratherum*," since they possess an articulated awn, which, however, is glabrous in contrast to that of the other species of his genus, in which the awns are plumose. Their leaf-structure, however, is identical with that of the other sections or subgenera, as described above, and the double parenchyma-sheath is very distinct in all three species. But the leaves of the other species of *Arthratherum* with plumose awns (by Bentham and Hooker and Hackel referred to Nees' "*Stipagrostis*") show a very different structure, which in all respects agrees with the descriptions and illustrations of some of these species in the works of Duval-Jouve and Volkens (l. c.).

In these the mesophyll is arranged as in the preceding species, but borders here on a large-celled parenchyma-sheath with chlorophyll, inside of which is no secondary green sheath, but only a layer of thick-walled mestome-parenchyma. There is the appearance of a mestome-sheath in the largest of the nerves, where this thick-walled parenchyma covers both the leptome and hadrome as an almost continuous sheath. But since this sheath is not present in the smaller bundles, and since it does not resist the effects of concentrated sulphuric

acid, and inasmuch as the cell-walls show distinct intercellular spaces, the conclusion is that it does not represent a mestome-sheath, but only some layers of mestome-parenchyma.

These species of the plumose-awned "*Arthratherum*" thus possess only one parenchyma-sheath around the mestome-bundles, and are thus quite distinct anatomically from the others, described above.

If we consider the other parts of the leaf, for instance, of *A. plumosa* L., we find the leaf much thicker than in any of the other species already examined, and the blade is strongly conduplicate without power to open. Both faces of the leaf, especially the upper, are furrowed, and the furrows are almost completely covered by overlapping, long, pointed hairs as well as by papillae with globular heads, very much resembling glandular hairs. These papillae were noticed only on the upper surface, while the furrows on the lower face were only covered by rather short, pointed hairs. The stomata are located in the furrows, and no bulliform cells are developed. The stereome occurs in large groups above and below the mestome-bundles, and is generally much better represented in this species, than we have seen in any of the other sections described above.

Between the ribs are narrow layers of colorless tissue, the function of which is evidently to store water, and the same tissue with exactly the same disposition was also, as we remember, observable in the many species of *Chaetaria* and other sections. We have, already, mentioned the mesophyll as bordering on a parenchyma-sheath, besides that inner layers of thick-walled mestome-parenchyma may, sometimes, imitate a mestome-sheath; we might state, furthermore, that the parenchyma-sheath is not continuous in the largest bundles, but plainly interrupted by the stereome. This condition certainly exists although disputed by Professor Schwendener, but we must concede that it is not usual. To prove it we have carefully treated the sections with concentrated sulphuric acid.

A corresponding structure is also to be observed in *A. acutiflora* Tr. et Rupr. (Algiers), *A. brachyathera* Coss. et Balb. (Algiers), *A. ciliata* Desf. (Tunis), *A. pungens* Dasf. var. *pennata* Trautv. (Russia) and *A. pennata* Trin. *(turkomannia)*, all of this same section "*Arthratherum*," with only a few unimportant departures. The furrows may, for example, be wider and more shallow on the upper face, thus leaving space for the development of typical bulliform cells, and very obvious in *A. pungens* var. *pennata*. Furthermore the mestome-bundles may not be confined to the prominent ribs, but may also be located in the spaces between these, beneath the bulliform cells and the adjoining broad layers of colorless tissue. But otherwise the structure is very much the same, and the parenchyma-sheath is equally large-celled and thin-walled in these species with no signs of a secondary one inside.

Taxonomic significance of the double parenchyma-sheath.

So far as known this new anatomical character occurs only in the family of the *Gramineae*. The vastness of this family may be realized from the fact that so extremely conservative an author as Bentham estimates the number of species to be about 3,200. Their distinction into tribes and genera is well known to be difficult under the guidance of morphological characters alone, and some recent botanists*) have already demonstrated the importance of the anatomical method as likely to lead to a better systematization of the family. Hence the discovery of any new anatomical character like this of the double parenchyma-sheath is of promise from the point of view of the systematist.

With this in mind the writer in choosing species for anatomical investigation purposely selected species representing different subgenera or sections of the genus; with this result that the new character is found to occur in certain sections and not in others of the genus *Aristida* as generally accepted at present. Let us therefore look into the history of *Aristida* as variously delimited by different agrostologists of the past and present.

Linnaeus**) founded the genus on the following species: *Adscensionis* and *americana*, while nearly thirty species were recognized at the time of Beauvais.***). This author referred the species to four genera: *Aristida*, *Curtopogon*,

*) Duval-Jouve (l. c.).

Same: Etude anatomique de quelques *Graminées* et en particulier des *Agropyrum* de l'Hérault. (Mém. de l'Acad. d. sc. et lettr. de Montpellier. Paris 1870.)

Güntz, H. E., Untersuchungen über die anatomische Struktur der *Gramineen*-Blätter in ihrem Verhältniss zu Standort und Klima. [Inaugural-Dissertation.] Leipzig 1886.

Guérin, P., Sur le développement du tégument séminal et du péricarpe des *Graminées*. [Thèse.] Paris 1899.

Hackel, Edw., Monographia *Festucarum* Europaearum. 1882.

Same, *Andropogoneae* in A. and C. De Candolle's Monographia phanerog. prodromus. Vol. VI. 1889.

Holm, Theo., A study of some anatomical characters of North American *Gramineae*. I—VII. (Bot. Gazette. 1891. p. 166, p. 219 and p. 275; 1892, p. 358; 1895, p. 362; 1896, p. 357; and p. 404.)

Lund Samsöe, Vejlednig til at kjende Graesser i blomsterlös Tilstand. (Dansk Frökontrol. Kjöbenhavn 1882.)

Pammel, L. H., The histology of the caryopsis and endosperm of some *Grasses*. (Contribution from the Shaw school of Botany. No. 12. St. Louis 1898.)

Sirrine, E. and Pammel, E., Some anatomical studies of the leaves of *Sporobolus* and *Panicum*. (Contribution Bot. Dept. Iowa College No. 1. Des Moines 1896.)

**) Linnaeus, C., Species plantarum. Ed. sec. Vol. I. Stockholm 1762. p. 121.

***) Beauvais, Palisot de: Essai d'une nouvelle Agrostographie ou nouveaux genres des *Graminées*. Paris 1812. p. 30 etc.

Chaetaria and *Arthratherum*, and a true *Aristida* was with Beauvais *A. lanata* Forskaal, which he characterized as possessing: "une véritable arête, simple non caduque et placée entre deux soies," while this same organ, the arista, is described as being "trifide au sommet, articulée et caduque" in *Arthratherum*. His *Chaetaria* comprises, on the other hand, the species in which the flowering glume*) is "plus ou moins prolongée en pointe, terminée par trois soies, le plus souvent égales," while the flowering glume in *Curtopogon* is described as "fendue, bilacinée, et une seule soie tordue entre les dents . . . ." Hence Beauvais drew a distinction between "seta" and "arista," the latter being characteristic of *Arthratherum* and *Aristida;* this organ is articulated and deciduous in the former, but not so in the latter.

Bentham and Hooker receive the genus in its old extent, but recognize as subgenera or sections Beauvais' genera: *Chaetaria* and *Arthratherum*, besides *Stipagrostis*, which was originally established by Nees as a proper genus. *Chaetaria* is by Bentham and Hooker an aggregate of both Beauvais' *Chaetaria* and *Curtopogon* besides that it includes *Streptachne* H. B. K. The section *Arthratherum* is with Bentham and Hooker only a part of Beauvais' genus, embracing the species with deciduous, but naked awns, while their section *Stipagrostis* comprises all those species in which the awns are plumose, namely *Arthratherum* (*pungens*) and *Aristida* (*lanata*) both of Beauvais.

A similar disposal is suggested by Hackel in his treatment of the family for Engler and Prantl's "Natürliche Pflanzenfamilien," and so is "*Chaetaria*" as a section designated to the species having naked, not deciduous awns; "*Arthratherum*" to those with naked and deciduous awns, while "*Stipagrostis*" includes the remaining in which these organs are deciduous and plumose. The genus-name "*Aristida*" as taken up by Beauvais only for *A. lanata* Forsk., which according to Vahl**) is identical with *A. plumosa* L., has not been adopted in this wise by subsequent authors, but as the name of the whole genus, including the sections, enumerated above.

Neither has Nees von Esenbeck's "*Stipagrostis*" been restricted to comprise those certain species, which he described in *Agrostographia capensis*,***) but has been extended so as to include also a part of Beauvais' *Arthratherum* with plumose awns, although Nees von Esenbeck him-

*) The term "empty glumes" is used here for "glumae vacuae" and "flowering glume" for "gluma florens" (Bentham and Hooker: Genera plant).

**) Vahl, Martin: Symbolae botanicae. Pars prima. Kjöbenhavn 1790. p. 11.

***) Halle 1853. p. 171.

self considered *Aristida plumosa* L. and *A. ciliata* Desf. as representatives of *Arthratherum*, but not of *Stipagrostis*. That Nees did not recognize *A. plumosa* L. as an "*Aristida*" in the sense of Beauvais was evidently in view of the fact that neither the diagnosis or the illustration in Beauvais' work are correct in this particular case: the articulation of the awn seems to have been overlooked, and so Beauvais' *Aristida* is, on his own grounds, inseparable from the other members of *Arthratherum*, as Nees also considered it to be. Nees does not even refer to this special figure of *Aristida lanata* Forsk., although he cites the others.

In bringing these facts together, the anatomical characterization and the systematic position of the species of *Aristida*, the following characters have been observed as the most important: "*Chaetaria*, *Curtopogon* and *Streptachne* possess the double parenchyma-sheath, while most of the species of *Arthratherum*, those with plumose awns, lack it. It is present in the three North American species: *A. californica*, *A. desmantha* and *A. tuberculosa*, which otherwise are closely related to the section *Arthratherum*, since their awns are articulated and deciduous, even if they are not plumose."

Allies of *Aristida*.

According to Bentham and Hooker the genus *Aristida* belongs to the tribe "*Agrostideae*" and is referred to a subtribe "*Stipeae*" of which *Stipa* is typical, and we must therefore look into *Stipa* and some of the other members of the *Stipeae*: *Oryzopsis*, *Eriocoma*, *Nassella*, *Piptochaetium*, *Muhlenbergia* and *Lycurus* as near allies of *Aristida*. Let us look into the anatomy and classification of some of these and naturally first of all:

Stipa L.

This genus exhibits much the same diversity in the structure of the awn (arista) as we have described above as being characteristic of *Aristida* and its sections: This organ occurs also in *Stipa* as continuous and persisting or as articulated and deciduous. Moreover the base of the awn is often twisted and of a considerable length, while the apex is either naked or distinctly plumose, but always entire, never trifid in any of the species of *Stipa*.

Aristella Bertol., *Streptachne* R. Br. and *Jarava* Ruiz et Pav. are some of the genera, which were formerly suggested as segregates of *Stipa*. The species are usually inhabitants of high plateaus, savannas and rocky soil. Some of these are frequently associated with various representatives of *Aristida*.

We had, therefore, expected that at least some of the species of *Stipa*, and especially those which possess a naked awn, would have shown the same structural peculiarity, which we noticed in the corresponding species of *Aristida*, namely the presence of a double parenchyma-sheath around the mestome-bundles; but as will be shown in the following pages this structure seems to be possessed by *Aristida alone*.

We have examined the leaf-structure of following species:

Stipa avenacea L. (Rocks on the Potomac-shore, Maryland).
" *capillata* L. (Meadows, Nercynsk; Davuria).
" *Charruana* Arech. (clayish soil, Montevideo, Uruguay).
" *comata* Tr. et Rupr. (Plains, Denver, Colorado).
" *filiculmis* Arech. (dry, stony plateaus, Montevideo, Uruguay).
" *filifolia* Nees (stony plateaus, Montevideo, Uruguay).
" *hyalina* Nees (grassy field, Montevideo, Uruguay).
" *latifolia* (Hack.) Arech. (clayey soil, Montevideo, Uruguay).
" *minor* Vas. (Chama, New Mexico).
" *Neesiana* Tr. et Rupr. (grassy fields, Montevideo, Uruguay).
" *papposa* Nees (dry, clayey soil, Montevideo, Uruguay).
" *pennata* L. var. *neo-mexicana* Thurb. (near Santa Fé, New Mexico, at an elevation of 5800 ft.).
" *stricta* Vas. (Hillsides, Mt. Adams, Washington Territory, at an elevation of 6–7000 ft.).

The leaves of these species are usually very rigid, but mostly glabrous on the lower face, except in *S. filiculmis*, and the upper face is either scabrous with short papillae (*S. avenacea* and *S. minor*) or provided with long hairs (*S. capillata*, *comata*, *pennata* var. *neo-mexicana* and *stricta*). The upper surface is more or less deeply furrowed in all the species, enumerated above, with the sole exception of *S. filifolia*, where both faces of the blade are perfectly smooth. The furrowed character of the foliage is constant in these species (excl. *S. filifolia*), whether the blade be flat or conduplicate, the latter being especially characteristic of *S. avenacea*, *S. filiculmis* and *S. pennata* var. *neo-mexicana*. It may be stated here, that we did not notice the midrib to be more projecting than the other ribs in the leaves with flat blades, while such differentiation was observed in the species with conduplicate leaves (*S. avenacea*, *filiculmis*, etc.). Bulliform cells occur in all the species, excepting *S. filifolia*, and are located only on the upper face, in the bottom of the furrows. The stomata we have observed to be mostly level with the epidermis and often confined to the upper face of the blade, along the sides of the furrows.

The mechanical tissue, the stereome, occurs as small groups on either face of the nerves, besides as a larger, isolated group on the leaf-margin; in *S. capillata*, however, this tissue was more amply represented and the cell-walls were heavily thickened to a greater extent than observed in the other species. *S. filifolia* is rather poorly provided with mechanical tissue, as the stereome is here developed only on the leptome-side of the mestome-bundles, but seemed to be absent from the hadrome side. — The mesophyll occurs mostly as a dense, homogeneous tissue of palisades, and the cells that border on the mestome-bundles radiate towards the center of these. In a few species, however, the palisades were observed to be relatively short (*S. minor* and *stricta*) while the entire mesophyll in *S. arenacea*, *capillata* and *filifolia* consisted of roundish cells with no differentiation into palisades. The mestome-bundles are located in the ribs of the blade, and *S. Charruana* is the only species of the genus examined, in which there are also mestome-bundles in the furrows, beneath the bulliform cells. In all the other species they are confined to the more or less projecting ribs, and are constantly arranged in one plane, alternately large and small. They are mostly oval in transverse section.

A green parenchyma-sheath surrounds each bundle. It is closed in all the nerves and thin-walled excepting in the larger mestome-bundles, where sometimes two or three cells on the leptome- and the hadrome-side may exhibit a thickening of the cell-walls, but only where the stereome borders directly on this sheath. Inside the parenchyma-sheath is a typical closed mestome-sheath of which the inner cell-walls are distinctly thickened in the larger mestome-bundles of all these species. This structure of the parenchyma- and the mestome-sheath was observed in our specimens of the genus, and not only in the species with naked awns, but also in those where this organ is plumose. In a word, the double parenchyma-sheath is wanting in *Stipa*; at least in the species, enumerated above. And neither Duval-Jouve, Güntz, Schwendener or Volkens (l. c.), who have also studied some species of the genus, make any mention of the presence of a double parenchyma-sheath. Only the mestome-sheath has been recorded by Prof. Schwendener as occurring in *Stipa pennata* and *tortilis*, to which may be added those we have enumerated above.

Oryzopsis Michx.:

O. asperifolia Michx. (Rich Woods, New-York).
O. canadensis Torr. (Plains, Minnesota).
O. melanocarpa Muhlbg. (Rocky Woods, Minnesota).
O. micrantha Thurb. (Plains, Denver, Colorado).

The leaves are quite broad and flat in the two species from woodlands: *O. asperifolia* and *melanocarpa*, but narrow in the two others. The general structure of the leaf is very uniform in these species and is suggestive of that which we have described above as characteristic of *Stipa*. We observe also in the leaves of *Oryzopsis* a smooth, more or less scabrous lower face in contrast to the upper, which is furrowed and usually provided with long, scattered hairs. The furrows are deepest and narrowest in the two species from the plains. In *O. melanocarpa* a midrib is plainly visible by its larger support of stereome and by containing more mesophyll than the others, but no bulliform cells or colorless parenchyma is developed above the midrib as is otherwise frequently observed in *Gramineae* with broad, flat leaves. The bulliform cells constitute very small groups, viewed in transverse section, in the bottom of the furrows of the narrow-leaved species, while in those with broader leaves these cells are not only larger, but they also form groups of much greater width than in the others.

The stomata are mostly to be found on the sides of the furrows and are level with the epidermis in *O. asperifolia* and *melanocarpa*, but sunk (below epidermis) in the two others. Stereome is especially well developed in *O. micrantha*, where it accompanies the mestome-bundles, and is observable on either face of these; it is less developed in the other species, but shows the same distribution, besides that it occurs also beneath the furrows in *O. canadensis* and *asperifolia*. In regard to the mesophyll, this tissue is only developed in *O. micrantha* as palisades throughout the blade, and those that border on the mestome-bundles radiate towards the center of these; in the other species this tissue consists mostly of much shorter, almost roundish cells, which, however, become somewhat stretched, where they approach the nerves, and attain there a form and position corresponding to those which we observed in *O. micrantha*.

A green, thin-walled parenchyma-sheath surrounds each mestome-bundle, and the cells are quite narrow, when viewed in transverse section. In cases where the stereome borders on the parenchyma-sheath, the cells of this sheath show then a thickening, as we noticed also in *Stipa;* but in no instance did we observe an interruption, caused by the adjoining stereome. A mestome-sheath with the inner cell-walls thickened is also to be found in these species, and is continuous in the large as in the small mestome-bundles; moreover one or a few strata of thick-walled mestome-parenchyma may be observed in the larger bundles between the leptome and hadrome.

The mestome-bundles are all located in the ribs, none in the

furrows. They are mostly oval (in transverse section) in *O. melanocarpa* and *asperifolia*, or nearly all orbicular in the two other species.

Eriocoma Nutt.

Eriocoma cuspidata Nutt. from the plains of Colorado possesses a narrow, conduplicate leaf-blade, the structure of which corresponds almost exactly to that of *Oryzopsis micrantha*, especially as to the deep, narrow furrows on the ventral face, the strongly developed mechanical tissue and the mesophyll, being represented by distinct palisades vertical on the leaf-blade or radiating towards the center of the mestome-bundles. The parenchyma- and mestome-sheaths show the same structure observed in *Oryzopsis*, but the mestome-bundles, which are mostly orbicular, are not in *Eriocoma* confined to the projecting ribs, but occur also in the furrows beneath the small bulliform cells.

The stereome and the mestome-sheath of *Eriocoma* appear to be relatively more thick-walled and porous than we observed in any of the species of *Oryzopsis*, even in *O. micrantha*, besides that the outer cell-wall of epidermis is very heavily thickened on the dorsal face of the leaf in this genus.

Nassella Desv.

N. trichotoma Hackel, from the mountains of Uruguay, has a very narrow and conduplicate leaf-blade, of which the dorsal face is not only protected by a heavily thickened epidermis, but also by a continuous mass of stereome, which covers the entire face until the margins in several broad layers. The ventral face of the blade is deeply furrowed and the thin-walled epidermis is on the ridges developed into long, pointed hairs, which cover the furrows, where small bulliform cells are observable; the stomata are sunk below the surface of epidermis and are located in the furrows. — Minor groups of stereome occur also on the upper face of the blade, above the mestome-bundles, connecting these with epidermis. The mesophyll represents a homogeneous tissue of roundish cells with no palisades around the mestome-bundles. These, the mestome-bundles, are surrounded by a thin-walled, colorless parenchyma-sheath and a mestome-sheath, continuous in all the bundles, with heavily thickened inner cell-walls; all the mestome-bundles are located in the projecting ribs, while the compact mesophyll occupies the furrows.

Piptochaetium Presl.

P. bicolor Desf. (Grassy fields, Montevideo, Uruguay).
P. lasianthum Griseb. (Stony ground, Montevideo, Uruguay).

P. stipoides Hack. (Grassy fields, Montevideo, Uruguay).

P. tuberculatum Desv. (Grassy fields, Montevideo, Uruguay).

The leaves of this genus differ from those of *Nassella* especially by the epidermis, which consists, here, of relatively large cells on the dorsal face of the blade, between the groups of stereome, which does not form a continuous cover as we have described above as characteristic of *Nassella*. Furthermore the ventral epidermis is in *Piptochaetium* plainly differentiated into relatively broad bands of bulliform cells located in the deep furrows between the prominent ribs. The lower face is smooth and glabrous in contrast to the upper, where short, prickle-like projections from the epidermis abound above the midrib and along the margins. The stomata occupy the same position as in *Nassella*.

The stereome is, then, much less developed in this genus than we observed in *Nassella*, and, moreover, it is often separated from the mestome-bundles by layers of mesophyll, especially in the lateral portions of the leaf-blade. While the mesophyll in *Nassella* was composed of a homogeneous tissue of roundish cells, we find in *Piptochaetium* distinct palisades radiating towards the center of the mestome-bundles.

The parenchyma-sheath is destitute of chlorophyll and the cells are relatively narrow and thin-walled; it is continuous in all the bundles and borders directly on a similarly closed mestome-sheath with moderately thickened cell-walls; thick-walled mestome-parenchyma was observed as a single layer between the leptome and hadrome.

Piptochaetium bicolor possesses the broadest leaf of these four species and the number of mestome-bundles averages about five on each side of the midrib, while in the other species, of which the leaves are very narrow, almost capillary, the number of nerves is only three in all, one on each side of the mid-rib; they, the mestome-bundles, are orbicular in all the species, when considered in transverse section.

Muhlenbergia Schreb.

The following species have been studied:

M. diffusa Schreb. (Deciduous forests near Brookland, D.C.),

" *distichophylla* Kunth (Arizona, at an elevation of 7,500 ft.),

" *glomerata* Trin. (Low grounds, Denver, Colorado),

" *gracilis* Trin. (Dry mountain-slopes near Golden City, Colorado, at an elevation of 6,500 ft.),

" *gracillima* Torr. (Hill-sides, New Mexico, at an elevation of 7,500 ft.),

M. mexicana Trin. (Deciduous forests in Brookland, D.C.).
" *sobolifera* Trin. (Deciduous forests in Brookland, D.C.),
" *sylvatica* T. et G. (Deciduous forests in Brookland, D.C.),
" *Willdenovii* Trin. (Woods, Kentucky).

The genus is, as already stated, a member of the *Stipeae* and is, thus, related to *Aristida*, but it contains only a few species, that are associated with this genus. The species are mostly woodland-plants or inhabitants of dry mountain-slopes, and vary very much in habit; some are decumbent and profusely branched with numerous lateral inflorescences (*M. diffusa*, *mexicana*, etc.), others are rigid and erect with a single, terminal panicle (*M. gracilis*, *gracillima*); thus we meet here with the same diversity in habit as we observed in *Aristida*, for example when we compare *A. dichotoma* with *A. stricta* or *A. lanata*. Furthermore the structure of the spikelets, and especially of the empty glumes, renders important characters for the distinction of the species and was formerly in connection with the habitual differences used for the establishment of independent genera, thus *M. diffusa* was a true *Muhlenbergia* with Beauvais, while *M. distichophylla* was segregated as *Podosaemum;* these with other segregates as *Vaseya* Thurb., *Clomena* Beauv., *Tosagris* Beauv. and *Trichochloa* Beauv. are now generally referred as mere sections of the genus *Muhlenbergia*.

Considered from an anatomical view-point some of these sections appear to possess certain peculiarities, which might prove useful to further studies for the disposal of the species in sections or perhaps subgenera. The material, which the writer examined, contained some apparently very distinct types, yet the number of species was too small for venturing to suggest the reëstablishment of some of the older genera of Beauvais for instance.

By the internal structure of the leaf the species fall naturally into two groups: the woodland-types, and those which inhabit the dry, rocky mountain-slopes.

The leaf of the woodland-types is thin, relatively broad and flat, with very shallow furrows on the upper face and scabrous. A midrib is plainly visible and is supported by a larger group of stereome than the others. Bulliform cells are well-developed between the ribs and are located only on the upper face of the blade in the furrows, but there are none above the midrib. In *M. glomerata* the midrib exhibits a large mass of colorless tissue on the upper face, which is separated from the epidermis by a few layers of stereome, covering the entire surface of the relatively broad midrib. No such colorless tissue was observed in any of the other species of this particular type either above the midrib or between the mestome-bundles of the lateral parts

of the blade. Stomata occur on either face of the leaf and are always level with the epidermis. The stereome is quite thick-walled, but occurs mostly in small groups on the leptome-side of the mestome-bundles, and on the hadrome-side of the larger bundles; besides there is an isolated group of stereome on the margin. — The mesophyll is quite dense and consists of palisades, most of which are arranged radially around the mestome-bundles, where they border on a thin-walled green and large-celled parenchyma-sheath. A mestome-sheath is also present and shows the usual thickening of the inner cell-walls, at least in the larger nerves, besides that a more or less thick-walled layer of mestome-parenchyma was observed between the leptome and hadrome. A cross-section of the mestome-bundles show most of these, even the larger, to be orbicular.

Comparing this structure with that of the species from drier ground, mountain-slopes or hill-sides, the following differences are notable. The leaves are thicker, much narrower and mostly conduplicate; both faces, but especially the upper, are distinctly furrowed, the furrows often deep and narrow. Epidermal projections abound on the upper face as pointed papillae or as long hairs (*M. gracilis* and *gracillima*), while the bulliform cells are much better developed in these species and border on layers of colorless tissue, located in the spaces between the ribs. The outer cell-walls of epidermis are heavily thickened on the dorsal face, and the stomata, which are level with the epidermis, are located on the sides of the furrows, surrounded by the epidermal projections. Groups of thick-walled stereome are to be seen above and below the mestome-bundles, and this tissue is especially well-developed in *M. gracilis* and *gracillima*, where it covers almost the entire dorsal face of the blade. — The mesophyll is very compact and consists of palisades, which radiate towards the center of the mestome-bundles. These are surrounded by a closed, large-celled and green parenchyma-sheath, the cells of which are quite thick-walled on the leptome- and hadrome-side, where the sheath is in contact with the stereome. A mestome-sheath is also developed*) as in the species mentioned above, besides

*) In describing the leaf-structure of *Muhlenbergia filipes* Curtis from the sand-strand of Ocracoke island, *M. capillaris* (Michx.) Kunth from dry sandy or rocky soil and *M. trichopodes* (Ell.) Chapm. from low pine-barrens, Mr. Kearney*) does not attribute a mestome-sheath to any of these species since the vessels in the smaller bundles were observed to border directly on the parenchyma-sheath. Having followed the study of these species we concluded with Mr. Kearney that the more or less completely closed sheath of thick-walled cells, which lie up to the parenchyma-sheath, were not to be considered as belonging to a mestome-sheath, but that they simply repre-

*) Kearney, Thomas H., The plant covering of Ocracoke island. (Contrib. U. S. Natl. Herb. Vol. V. No. 5. p. 285. Washington 1900.)

that we find layers of thick-walled mestome-parenchyma in the larger bundles between the leptome and hadrome. In *M. distichophylla* the cells of the mestome-sheath show an excessive thickening in comparison with the other species, and the companion-cells of the sieve-tubes are very thick-walled in *M. gracillima.* Viewed in transverse section the outline of the mestome-bundles is either oval (*M. distichophylla*) or orbicular (*M. gracilis* and *gracillima*). Besides these two types of leaves exhibited by *Muhlenbergia*, there is still a third one, characteristic of *M. filipes* Curtis, and which has been described by Mr. Kearney (l. c.). The leaf of this species is permanently conduplicate and has deep furrows on either face of the blade. The mestome-bundles are located in the very prominent ribs, and are almost embedded in a large mass of colorless tissue occupying the ventral ridges over the larger mestome-bundles, besides that it occurs as forming layers on the dorsal face of the leaf-blade.

Lycurus Kth.

L. phleoides H. B. K., which is also a member of the "Stipeae," was collected on dry plains near Manitou, Colorado, and represents a type that has structural characteristics in common with other *Gramineae* of similar habitat.

The leaf is conduplicate, furrowed, and both faces are very scabrous with numerous short, thick-walled papillae, and there are long, pointed hairs scattered over the upper face. Stomata occur on both faces near the shallow furrows and are level with the epidermis. Intervening between the ribs are small groups of bulliform cells, which border on a few rows of colorless tissue, extending to the dorsal epidermis. The stereome is represented by a large group on the lower face of the midrib, and a similar large one on each leaf-margin; otherwise this tissue occurs only as a few cells on either face of the ribs. — The mesophyll consists of palisades arranged radially around the mestome-bundles, these again being surrounded by a thin-walled, green and large-celled parenchyma-sheath and by a mestome-sheath, which shows a very heavy thickening of the inner cell-walls in the larger bundles. The outline of the

sented mestome-parenchyma. But since we now studied other species of *Muhlenbergia* and from very different localities we have arrived at the conclusion that the three species actually possess a mestome-sheath. Moreover by renewing the examination of *M. capillaris* we have found that the interruption of the mestome-sheath by the small vessels varies somewhat between apex and base in the same leaf, and that there are many cases in which even the smallest bundles possess a completely closed inner sheath. Testing the sheath with concentrated sulphuric acid it shows the same power of resistance that is usually characteristic of true mestome-sheaths, hence we infer that *Muhlenbergia capillaris* possesses both a parenchyma- and a mestome-sheath.

mestome-bundles, when examined in transverse section, is mostly orbicular in *Lycurus*.

These allies of *Aristida* are thus readily distinguished from that genus (not including those with plumose awns) by their having only one parenchyma-sheath, and from all the species of *Aristida* examined, by the presence of a mestome-sheath. —A colorless parenchyma, mostly located between the ribs, is developed in *Lycurus*, *Muhlenbergia gracilis*, *gracillima* and *distichophylla*, but is wanting in the other species of *Muhlenbergia* and was not noticed in any of the species belonging to the genera: *Stipa*, *Oryzopsis*, *Eriocoma*, *Nassella* and *Piptochaetium*, while it exists in all the *Aristidae*. The mesophyll is in most species developed as palisades, but it occurs also, though seldom, as a homogeneous tissue of roundish cells in *Stipa avenacea*, *capillata*, *filifolia* and in *Nassella*. A mesophyll consisting of both palisades and roundish cells was found in *Oryzopsis micrantha*.

Thus is *Aristida* s. s. considered from an anatomical point of view a well-marked genus, when compared with its nearest allies, at least with the species, which we have had an opportunity to examine, and the most salient structural peculiarity is, of course, the presence of a double parenchyma-sheath. The constant absence of a mestome-sheath is of less importance, although it constitutes an excellent anatomical character in this particular case. — The subgenus *Arthratherum* contains, as stated above, some species that have and some that have not a double parenchyma-sheath, but in none of these does there appear any trace of a mestome-sheath. In this way the three species with naked awns in which two parenchyma-sheaths are developed appear to be more closely connected with the genus, than those with plumose awns and a single parenchyma-sheath.

The lacking of a mestome-sheath in both may possibly indicate some closer affinity to the other subgenera of *Aristida* than to *Stipa* and all those of the same tribe, which have mestome-sheaths.

These structural divergences are, thus, to be found in a large number of species, which are not only considered as near allies of *Aristida* but they are, moreover, in many instances associated with the genus. *Stipa avenacea* and *Muhlenbergia capillaris* inhabit the same kind of soil as several species of *Aristida*, viz.: *Aristida oligantha*, *gracilis*, *purpurascens*, etc., while *Aristida fasciculata* inhabits the plains of Colorado in company with species of *Stipa*, *Oryzopsis* and *Eriocoma*.

Having thus considered the leaf-structure in genera to be reckoned among the nearest allies of *Aristida*, we shall now present a few notes upon the corresponding structure of other

genera, among which are several species that are often found to be associated with *Aristida*, especially on the plains and in the dry fields, which are not, however, nearly allied to that genus.

Genera of *Gramineae* associated with, but not related to *Aristida*.

Sporobolus R. Br.

We have examined the following species:

S. airoides Torr. (Valleys, Kansas),
S. argutus Kth. (In moist soil, river-bottoms, Kansas),
S. asper Kth. (On dry rocks at Great Falls of the Potomac, Maryland),
S. asperifolius Thurb. (Plains, Denver, Colorado),
S. brevicalyx Scribn. (On rocks in the Spruce-Zone near Graymont, Clear Creek Cañon, Colorado, at 10,300 ft. alt.),
S. brevifolius Nutt. (Durango, Southern Colorado),
S. cryptandrus Gray (Plains, Denver, Colorado),
S. cuspidatus Scribn. (Dry hills and uplands, in sterile soil, Kansas),
S. depauperatus Vas. (Damp places along creeks at Twin Lakes near Leadville, Colorado, 9265 ft. alt.),
S. indicus R. Br. (Clayish soil, Eustis, Florida),
S. junceus Kunth. (High-Pine-woods near Eustis, Florida),
S. pungens Kunth. (Sandy sea-shore near Cannes, France),
S. tenacissimus Beauv. (Dry fields, Montevideo, Urug.),
S. vaginaeflorus Vas. (Dry fields near Great Falls of the Potomac, Maryland),
S. virginicus (L.) Kth. (Sandy sea-shore, Tampa, Florida).

The genus was established by Robert Brown upon species in which the empty glumes are very unequal in length and both shorter than the flowering glume (*S. indicus*); but since his time a number of other species of quite different type have been referred to the genus, namely species of Beauvais' *Vilfa*, in which the empty glumes are subequal and mostly longer than the flowering glume (*V. virginica*, *pungens*, etc.). Nevertheless *Vilfa*, as distinguished by Beauvais, has not gained much recognition and is not regarded as anything but a synonym of *Sporobolus* in the works of Hackel, Bentham and Hooker. There are cases in which the length of the empty glumes in proportion to the flowering glume does not afford any very distinct character for the separation of these two genera, especially in cases where the empty glumes are very unequal in length, and the superior of these being of the same length as the flowering glume, or sometimes even a little longer; such species would naturally have

to be referred to *Sporobolus:* "with the empty glumes unequal," while the length of the upper empty glume makes them referable also to *Vilfa.* However many species are so distinct "*Vilfae*" that one would not be surprised if some future monographer of *Sporobolus* should refer them to this genus, *Vilfa.*

In habit *Vilfa* scarcely differs from *Sporobolus; S. Virginicus* and *S. pungens*, both *Vilfae* with Beauvais, are certainly very characteristic species by their stoloniferous habit, but they are just as unlike most of the other species of *Vilfa* as those of *Sporobolus; S. vaginaeflorus* and *S. cuspidatus*, both *Vilfae*, represent a mode of growth which is also to be observed in several species ot *Sporobolus* proper, for instance *S. depauperatus* and *brevicalyx*, while *S. argutus* (*Vilfa*) has the habit of *S. junceus* and *tenacissimus* with a single, terminal panicle. Anatomically these species of *Sporobolus* are not to be distinguished as two genera, at least not in regard to the structure of their leaves.

Sporobolus is a member of the *Agrostideae*, of the subtribe *Euagrosteae* according to Hackel, and has a very characteristic fruit. Its pericarp is thin, dehiscent, free from and merely enclosing the seed; a fruit known in but few other genera, namely, *Eleusine*, *Crypsis* and *Heleochloa*. Many of the species are inhabitants of open plains and prairies, and are frequently associated with species of *Aristida*. The leaves are usually narrow, but flat with no prominent midrib; both faces of the blade are furrowed in several species: *S. argutus*, *brevicalyx*, *cryptandrus*, *depauperatus* and very deeply in *S. asperifolius*, while in the remaining species the lower face is quite smooth. The leaf-surface is mostly scabrous by short papillae, or by long, prickle-like projections as in *S. cuspidatus;* glabrous leaves are possessed by *S. asper*, *cryptandrus* and *vaginaeflorus*.

Bulliform cells do not occur above the midrib, but between each two ribs on the upper face of the blade; they are well-developed in *S. airoides*, *argutus*, *cryptandrus*, *depauperatus*, *indicus* and *vaginaeflorus*, but are more or less reduced in the others, especially in *S. pungens*, *virginicus* and *junceus*.

The outer cell-wall of epidermis is often heavily thickened on both faces of the blade, and the stomata, which are distributed on both faces of the leaf, are level with the epidermis in most of these species, or slightly projecting (*S. brevicalyx* and *cryptandrus*).

The stereome is relatively but weakly developed in *Sporobolus*, and accompanies the mestome-bundles as small groups on either face of these, besides that the outermost portion of the margin contains an isolated bundle of this tissue. Between

the ribs, underneath the bulliform cells may be found a colorless tissue of a few, one or two, rows of cells (*S. asperifolius*, *pungens*, *virginicus*), or only near the leaf-margin (*S. asper*, *vaginaeflorus*) as a few subepidermal layers on the upper face; in *S. junceus* the colorless tissue is much farther developed and occurs not only between the ribs, but also above the mestome-bundles and constitutes a very prominent portion of the high ridges.

A somewhat different structure is exhibited by *S. Hookerii*, which has been studied by Sirrine and Pammel (l. c.), where a larger mass of colorless tissue occupies the upper central portion of the leaf-blade, covering the midrib with its adjoining four mestome-bundles, besides that it occurs also as a few layers beneath the bulliform cells in the furrows. — The mesophyll consists of palisades, which radiate towards the center of the mestome-bundles in all the species, which we have examined.

A single and green parenchyma-sheath is observable around the mestome-bundles; it is generally large-celled, but the cell-walls are either thin or distinctly thickened, the latter being characteristic of *S. airoides*, *brevifolius*, *cuspidatus*, *pungens* and *vaginaeflorus*; a parenchyma-sheath of small and thin-walled cells was observed only in *S. junceus*.

Inside the parenchyma-sheath is a mestome-sheath, noticed in all the species,*) of which the inner cell-walls are usually thickened, very heavily in *S. airoides*, *asper*, *indicus*, *junceus* and *pungens*. — As to the location of the mestome-bundles, they are in most of the species confined to the ribs, but may also be seen in the furrows in a few species (*S. airoides*, *asper* and *vaginaeflorus*); a transverse section shows their outline to be oval or orbicular, the latter form being the most frequent, but often mixed with the former in the same leaf (*S. asper*, *brevi-*

*) In describing the leaf-structure of *Sporobolus virginicus* (L.) Kth. Professor Warming (Halofyt-Studier, p. 227) states that the mestome-bundles viewed in transverse section are arranged in a zig-zagged line; the larger being located in the projecting ribs, the smaller in the furrows; that the cells of the mesophyll do not present any very pronounced shape as palisades, and that epidermis of the lower face is generally very large-celled. He compares this structure with that of *S. spicatus*, figured by Volkens (l. c.). But the specimens which we examined of *S. virginicus* from Florida exhibit a structure so different from that described by Professor Warming, that the material examined by him must have been wrongly identified as of *S. virginicus*. The leaf of real *S. virginicus* has no mestome-bundles in the furrows. The mesophyll represents a true and very distinct palisade-tissue, the cells of which radiate towards the center of each mestome-bundle, besides that the cells of the epidermis are small on the lower face. Moreover a mestome-sheath is plainly visible in this species, and is quite thick-walled, in the larger bundles, while no such sheath is mentioned by Professor Warming, as occurring in the material, which he examined. — The structure of *S. virginicus* is thus very different from that of *S. spicatus* (fide Volkens l. c.), but is almost identical with that of *S. pungens* from Europe.

folius, *cuspidatus*, *junceus*, etc.). The mestome-bundles are thus either all orbicular, or this form may occur together with the oval, but we observed no instance where the latter was the only one represented.

Calamovilfa longifolia (Hook.) Scribn. (Plains, Denver, Colorado.)

This genus is also a representative of the "*Euagrosteae*" and is very nearly related to *Ammophila* Host. (*Psamma* Beauv.) by the chartaceous flowering glume; but it has the large and loose panicle of *Calamagrostis*, to which the species was also referred by Hooker. — There is still another species of this little genus, which by Gray was placed with the former as a section of *Calamagrostis*, but Hackel proposed the segregation of these species to form a genus "*Calamovilfa*:" "Empty glumes unequal; flowering glume one-nerved; rhachilla not prolonged." We have only examined *C. longifolia*, which grew socially on the plains near Denver and Manitou, Colorado. It is the tallest of the *Gramineae* of the plains and is strongly stoloniferous. — The leaves are long, relatively broad and are equally furrowed on both faces. A few, scattered, hairs occur on the upper face, while the lower is nearly glabrous. There are small groups of bulliform cells in the furrows on the upper face, which cover narrow layers of colorless tissue between the ribs. The stomata are almost level with the epidermis and occur on both faces of the blade.

A thick-walled stereome accompanies the mestome-bundles and borders on the parenchyma-sheath on the leptome and the hadrome-side of these. The mesophyll, which is thus confined to the ribs, consists of palisades, all of which are arranged radially around the mestome-bundles. These are surrounded by a large-celled, thin-walled and green parenchyma-sheath, and also by a moderately thickened mestome-sheath, which is continuous in all the bundles. Several layers of thick-walled mestome-parenchyma were observed around the leptome. The outline of the mestome-bundles is always oval.

Buchloë dactyloides Engelm.,

the famous "Buffalo-grass," covers large areas of the dry plains in North America, and is frequently associated with various species of *Aristida*. It belongs to the "*Chlorideae*," and is mostly dioecious, the two sexes being very unlike.*) The leaves are plane, and the lower face has narrow furrows between the ribs, while the upper is nearly smooth. There are many short papillae on both faces of the blade, outside the subepider-

*) The best figure of this peculiar, little grass is given by Engelmann in his paper: "Two new dioecious grasses of the United States." (Transact. St. Louis Acad. Sc. Vol. I. St. Louis 1859. p. 431.)

mal stereome, and long unicellular, pointed hairs are scattered over both faces. Between the ribs occur large bulliform cells, which pass gradually over into a single layer of colorless tissue, extending to the lower epidermis. The outer cell-wall of the epidermis is strongly thickened on both faces and covered by a distinct smooth cuticle. Stomata occur on the sides of the furrows and near the bulliform cells on the upper face. They are surrounded by papillae, but are otherwise level with the epidermis. There is not much stereome in the leaf, and it forms only small groups above and below the mestome-bundles, mostly separated from the parenchyma-sheath by the palisades, and a small, isolated group is located on the leaf-margin. The mesophyll is confined to the ribs, where it surrounds the orbicular mestome-bundles as radially arranged palisades. These border on the single parenchyma-sheath, which is large-celled, somewhat thick-walled, and contains starch.

The mestome-bundles are thus surrounded by only one parenchyma-sheath, which is continuous in all the bundles. Inside is a true mestome-sheath, which presents some modifications: The cell-walls are heavily thickened in the larger bundles, but only around the leptome and on the sides of the hadrome; they are thin just above the hadrome, but otherwise this sheath is constantly continuous in the large mestome-bundles. But in the smaller mestome-bundles the sheath is not only thin-walled with the exception of one or two cells beneath the leptome, but it is also interrupted by the two vessels, at least in some instances. Such interruptions of the mestome-sheath by the vessels has been noticed before, but is not, however, frequently met with, and it is often difficult to decide whether these cells belong to a mestome-sheath or whether they are to be considered as mestome-parenchyma. In the present case the test with concentrated sulphuric acid proved these cells to represent a mestome-sheath. A layer of thick-walled mestome-parenchyma occurs between the leptome and hadrome, but only in the largest bundles.

Schedonnardus paniculatus (Nutt.) Trelease

is also a member of the *Chlorideae*, and we collected this together with the preceding on the plains near Denver, Colorado.

The leaf is conduplicate with a distinct midrib, and is furrowed on both faces, though but slightly so on the lower. Most of the epidermis cells are extended into short obtuse papillae, rendering the leaf faces very scabrous; but no proper hairs were observed. Small bulliform cells are developed on the upper face, in the bottom of the narrow furrows, which in this species pass over into a colorless tissue, that extends to the

lower epidermis, except on the sides of the midrib, where a small group of sub-epidermal stereome is located. The stomata occur on both faces of the blade near the furrows and are slightly projecting, surrounded by the papillae. The stereome is much better developed in this genus than in *Buchloë*, and forms a large thick-walled group below the midrib, triangular in transverse section, besides that a similar large group is seen on the leaf-margin. Minor groups of this tissue also occur on the leptome side of the larger mestome-bundles, but seems to be almost totally absent from the hadrome-side.—Examining the structure of the mesophyll and the mestome-bundles with their parenchyma- and mestome-sheath, we find this to be absolutely identical with that of *Buchloë*. *Schedonnardus* is, nevertheless, readily distinguished from *Buchloë* by the strongly developed stereome in the midrib, the small bulliform cells, and by the absence of hairs, even if the other parts of the blade show a similar composition.

Bouteloua oligostachya Torr.

This grass belongs also to the *Chlorideae* and is very frequent on the dry plains of Colorado, where it forms large and very dense patches, often resembling the staminate plant of *Buchloë*. The leaf-structure is so much like that of *Buchloë* in regard to the shape, the development and the distribution of the various tissues, that we are unable to point out any other difference than that the leaf of *Bouteloua* is a little thicker; the mestome-bundles are nearly all oval and the broader ribs are, on both faces, covered by one or two sub-epidermal layers of thick-walled stereome, which in transverse section forms a long, linear group above and below the ribs, besides that stereome also occurs in the furrows of the dorsal face of the blade. But the structure of the two is identical as to the palisades, the parenchyma- and the mestome-sheaths.

Of these three *Chlorideae*, *Schedonnardus* shows a large midrib supported by a large mass of stereome. A very different structure is, however, exhibited by *Chloris petraea* Sw. from sandy seashores, which has been described and figured by Duval-Jouve and Kearney (l. c.) and which possesses a large colorless tissue underneath the entire ventral epidermis, which is here differentiated into a broad band of bulliform cells above the strongly carinate midrib. A single parenchyma- and a mestome-sheath was also observed in this genus, besides that the mesophyll consists of palisades, arranged radially around the mestome-bundles. But the leaf of *Chloris petraea* is smooth, without furrows, and is scabrous only on the lower face.

Glyceria airoides Thurb. *(Festucaceae).*

Besides being very abundant in alkaline soil on the plains of Colorado, this species may also ascend the mountains to an elevation of 10,300 ft., where it occurs on dry, rocky slopes. It is, thus, one of the *Gramineae*, characteristic of the plains, and as will be shown in the following pages, it exhibits a leaf-structure which is so very much unlike that of other species of *Glyceria*, hitherto examined by various authors. The leaf is very narrow, deeply furrowed on the upper face and covered with quite long, unicellular, pointed hairs on both faces of the blade. Small bulliform cells are present in the furrows, but none are developed above the midrib; the cell-walls of epidermis are much thickened on both faces of the blade, and the stomata, level with the epidermis, are located in that part of epidermis which covers the mesophyll, but are most frequent along the sides of the furrows. The stereome is not very thick-walled, and accompanies the mestome-bundles as large groups on the leptome-side, bordering on the parenchyma-sheath but as only a few layers or a few cells on the hadrome-side of these, separated by layers of mesophyll. The palisade-tissue is not as typically developed as in other *Gramineae* from the same localities, and the cells are usually relatively short, except those that border directly on the parenchyma-sheath. These are a little longer and are arranged radially around the nerves. No lacunes were observed in the mesophyll, and we mention this, because these are very conspicuous in leaves of other species of *Glyceria*. The larger mestome-bundles are oval, and the smaller orbicular in transverse section; they are located in the ribs, and the mediane of these is not more prominent than the others. They are all surrounded by a small-celled, thin-walled parenchyma-sheath, which contains chlorophyll, and which is completely closed in all the bundles. There is also a mestome-sheath of cells with the inner wall very thick and porous in most of the bundles.

Glyceria airoides has then the same principal leaf-structure as other genera inhabiting the dry plains: namely the deep furrows, the hairy covering, the dense mesophyll of palisades around the mestome-bundles and the relatively narrow leaf-blade.

Duval-Jouve (l. c.) has described and figured leaves of *Glyceria aquatica*, *fluitans* and *nervata*, in which wide lacunes traverse the blade between the nerves, and the mestome-bundles do not form any projecting ribs in these species, except the mediane one, which is located in the keel. The leaf of *G. fluitans* is, however, deeply furrowed on its upper face, but the mestome-bundles are, nevertheless, to be found in the bottom of the furrows while the ridges are merely occupied

by a few layers of mesophyll, surrounding lacunes of very great breadth. This same author has also described *G. festucaeformis*, which to some extent is more like our *G. airoides*, as to its leaf, which is quite thick and narrow, besides that the mesophyll is compact without any lacunes. It differs, however, from that of *G. airoides* by its smooth surface and by the large colorless tissue, that covers the hadrome of the larger mestome-bundles, as well as in that no hairs are developed.

Distichlis spicata (L.) Greene (*Festuceae*).

This grass, originally described by Linnaeus as *Uniola spicata*, and later by Rafinesque as *Distichlis maritima*, inhabits salt-marshes along the Atlantic and Pacific coasts of this country and is also very frequent in the interior on low alkaline plains. Our material was collected near Denver in Colorado.

The structure of the leaf resembles strikingly that of *Calamovilfa*, but no hairs are developed, while short papillae abound on both leaf-faces: on the ridges of the upper, and in the shallow furrows of the lower. The blade is very deeply furrowed above, and the furrows are occupied by large and well-developed bulliform cells. Epidermis is everywhere very thick-walled, but especially outside the stereome on the lower face. Stomata are present on the sides of the furrows and are almost level with the epidermis, but surrounded by thick, curved papillae. A colorless tissue of about two rows of cells in four layers is located underneath the bulliform cells, in the broad spaces between the ribs.

The stereome is thick-walled, but occurs only in small groups above and below the mestome-bundles, but there is no large group, supporting the midrib, and the margins have only a very small group of this tissue. The mesophyll is dense and consists principally of a single layer of palisades, arranged radially around the mestome-bundles. These have the usual parenchyma- and mestome-sheath, of which the former is large-celled, a little thick-walled and contains chlorophyll. The latter is strongly thickened and is only continuous in the largest mestome-bundles. Many of the companion-cells have also very thick walls; thus the leptome presents a very peculiar aspect, appearing as if intermixed with stereome. None of the mestome-bundles showed the orbicular outline, which is otherwise characteristic of these inhabitants of dry plains and deserts.

Our material of this grass was collected in alkaline soil on the plains of Colorado, but the leaf-structure is identical with that of specimens from the sea-shore. In a previously published paper (Botan. Gazette 1891. p. 275) we have described

Distichlis from various parts of this country, and the structure is in all important points the same in plants from the salt-plains of the interior, and in those from the salt-marshes of the sea-board.

Munroa squarrosa Torr. (*Festuceae*).

This is, like *Buchloë* and *Schedonnardus*, one of the most characteristic grasses of the plains. It is annual, but very much branched and forms small, glaucous cushions of very rigid leaves, while the flowers are barely visible, being hidden in the leaf-sheaths. The culms are very short and the leaves crowded at the apex, each supporting a minute branch with a large prophyllon, of which the two nerves are extended into quite long, stiff and pungent awns, reflexed and divergent.

The leaf as to its anatomy reminds us very much of that of *Buchloë*, but has more stereome throughout, especially underneath the leptome and the colorless tissue. The blade is narrow, furrowed on both faces, but the furrows are wide and shallow. Hairs are absent, but pointed prickle-like projections are scattered on the upper face, while the lower is slightly scabrous with short papillae. The bulliform cells are quite large and cover a few layers of colorless tissue. Stomata are distributed on both faces, near the furrows. As stated above, the stereome is much better represented in this grass than in *Buchloë*, but shows otherwise the same distribution. The mestome-bundles are relatively small, all orbicular and surrounded by a single layer of palisades, a large-celled, thin-walled and green parenchyma-sheath, and a mestome-sheath with the inner cell-walls much thickened and porous in the larger mestome-bundles.

Scleropogon Karwinskianus (Fourn.) Benth. (*Festuceae*).

This dioecious grass from the prairies of Texas is remarkable for the very different aspect of the two sexes, which is so great that without proof one would never suspect them to belong to the same species. The flowering glume of the staminate spikelet is only minutely three-toothed at the apex, while in the pistillate plant it is provided with three very long, firm and sometimes twisted awns. The leaves are relatively short, flat and furrowed on both faces, scabrous with short, obtuse papillae. There is a band of well-developed bulliform cells in the furrows between each two mestome-bundles on the upper face of the blade with the outer walls thickened like the other epidermal cells. Stomata occur on both faces and are almost level with the epidermis. The stereome is very thick-walled and forms a large group below the midrib, and also accompanies the lateral nerves on the leptome- and hadrome-

side of these. A dense palisade-tissue surrounds the mestome-bundles and also occupies the spaces between these, underneath the bulliform cells, excepting near the midrib, where this space is taken up by a few layers of colorless tissue. The cells of the palisade-tissue are arranged radially towards the center of the mestome-bundles and border directly on a thin-walled, large-celled, green parenchyma-sheath, inside of which is a mestome-sheath of thick-walled cells. There is also in the larger bundles a layer of thick-walled mestome-parenchyma between the leptome and hadrome. The outline of the bundles in transverse section is oval in the larger ones, and orbicular in the smaller, the latter predominating.

On the whole, the general leaf-structure of these associates of *Aristida* displays the same and constant development of a single, mostly large-celled parenchyma-sheath, besides a mestome-sheath inside this. — Furthermore the mesophyll consists of palisades arranged radially around the mestome-bundles, and this cell-form is the prevalent in these species; though *Glyceria* is exceptional in having not only palisades, which border directly on the parenchyma-sheath, but also some layers of much shorter and nearly roundish cells with chlorophyll between the ribs, underneath the bulliform cells. A colorless tissue was observed in most of the species; *Glyceria* and several species of *Sporobolus* (*S. airoides*, *argutus*, *brevicalyx*, *cryptandrus*, *indicus*, etc.) lack this besides that it is only developed as a small group, one on each side of the midrib in *Scleropogon*, or only above the midrib, as was observed in *Sporobolus tenacissimus*. But otherwise the structure seems very uniform and quite similar to that of the allied genera, besides also exhibiting several points in common with *Aristida*.

Deductions.

Contrary to our expectation we have not succeeded in detecting the double parenchyma-sheath in any of the genera, that are allied or associated with *Aristida*, and it constitutes, no doubt, a generic character. Its absence from some of the *Aristidae* does not seem to indicate that such modifications in structure are induced by diversity in environment, but it seems more probable that these species, in which there is only one sheath developed, should be removed from *Aristida* proper, and especially because their morphological characters are so very distinct. When we at first noticed the two chlorophyll-bearing sheaths in *Aristida fasciculata*, we thought that the innermost might correspond to the one which Haberlandt (l. c.) detected inside the mestome-sheath of *Cyperus*, but

Professor Schwendener has kindly informed us that he is more inclined to consider them as histologically distinct, even if their function be identical. The outermost of these sheaths compares, on the other hand, with the ordinary parenchyma-sheath, known so well from the mestome-bundles in *Gramineae*, *Cyperaceae*, *Juncaceae*, etc.*), and can only be defined in this way; to consider it as a mestome-sheath is at once excluded by the fact that it contains chlorophyll, furthermore on account of the shape of the cells.

These sheaths as they occur together in our *Aristidae* may possibly be regarded as an inherited character rather than an epharmonic, since they are equally well developed in species from arid plains, rich prairies, hill-sides, fields and low pine-barrens, while at the same time they are wanting to many species from allied and associated genera of the order.

And we have also shown that it is not a structure that is especially characteristic of *Aristidae* only from the plains and prairies in this country, but that other members of the same section, *Chaetaria* from Asia, Africa and Australia, exhibit exactly the same peculiarity. — Characteristic of these *Aristidae* with a double sheath is the absence, and evidently the constant absence, of a mestome-sheath, besides that there is very little thick-walled mestome-parenchyma visible in these species; the plumose-awned *Aristidae* have no mestome-sheath either, but the mestome-parenchyma is in these species very prominently thick-walled and occurs often as almost continuous sheaths around the leptome and hadrome, thus simulating a true mestome-sheath. The presence of a mestome-sheath in all the other *Gramineae*, which we have studied, and which may be added to those already enumerated by Professor Schwendener (l. c. p. 413) as possessing this sheath, seems surely to confirm the statement made by this author (l. c. p. 414) that its development does not depend on the surroundings, climate or soil. Because we found the mestome-sheath developed in several genera from the plains, prairies and woodlands, of which many species inhabit very different localities, but in which this particular sheath is, nevertheless, present with no modification whatsoever. The constant lacking of this same sheath in *Aristida* from so many and very remote stations speaks also in favor of this supposition.

But it would not be natural to divide *Aristida* or perhaps any other genus simply on account of peculiarities in structure,

*) Pée-Laby describes the ordinary parenchyma-sheath of the *Gramineae* and makes the following statements: "La présence de cette gaine verte ou incolore, n'a pas été signalée, à ma connaissance" and "Schwendener est le seul qui ait figurée . . . . . mais il n'en fait pas une mention spéciale dans le texte!" — (Etude anatomique de la feuille des Graminées de la France. Annales des sc. Botanique. Paris 1893. p. 237 and 238.)

and we, therefore, do not approve of the separation of certain genera of *Cyperaceae* on account of the presence or absence of the green sheath inside the mestome-sheath. We allude to Dr. Rikli's suggestion (l. c.) that *Cyperus* for instance must be considered as two distinct genera: Chloro- and Eu-*Cyperus* in respect to the presence or absence of this inner sheath. Having studied many species of *Cyperus* from North America and from very diverse localities, we have, so far, observed this same sheath in no less than four subgenera: *Eucyperus*, *Pycreus*, *Mariscus* and *Diclidium*; thus if *Cyperus* should be divided into *Chloro-* and *Eu-cyperus*, each of these would actually become an alliance of very diverse types, of which several parallel forms would have to be separated and referred, some to *Chloro-* others to *Eu-cyperus*. In this instance the morphological characters should not be under-estimated, even if the anatomical characters be ever so prominent.

It is different, however, with *Aristida*, where excellent morphological characters accompany the anatomical distinction, and it has surprised us, that the plumose-awned *Stipae* appear to be anatomically inseparable from the others; we had expected to find in these *Stipae* diversities in structure analogous to those observed in *Aristida*.

Thus is the presence of this double sheath and the absence of a mestome-sheath the most conspicuous character, by which the North American and some other species of *Aristida* are distinct from their allies. But otherwise, as we have seen above, the leaf-structure in general is much the same in all of these. The more or less deeply furrowed surface of the blade; the development of epidermis into bulliform cells between the ribs, but not above the midrib; the presence of papillae or hairs bent over the furrows with the stomata; the palisades arranged radially around the mestome-bundles and finally the distribution and relative development of the stereome, all these characters seem almost uniformly developed in these species with but a few exceptions. The colorless tissue, the function of which is generally explained as being for the storage of water, is on the other hand very unequally represented in these plants; it is developed in many and located underneath the bulliform cells in the furrows, but it lacks in *Stipa*, *Oryzopsis*, *Eriocoma*, etc., several of which are among the most frequently associated with *Aristida*, besides being among its nearest allies.

If we finally consider the habit of these plants, it does not seem as if any special type is characteristic, neither among the species from the plains, the prairies or the fields. Caespitose and stoloniferous species occur together; the culms may be simple or much branched with numerous lateral inflorescences;

the leaves may be almost vertical or horizontal, flat or conduplicate, at least when dry, but usually with power to open, when the atmosphere becomes moist; the leaf-sheaths may be narrow or much inflated, thus partly enclosing the inflorescence, as in the pistillate plant of *Buchloë*, in *Munroa*, *Sporobolus cryptandrus*, *vaginaeflorus*, *asper*, etc., and a similar case is also recorded by Warming*) as characteristic of several *Gramineae* from sandy sea-shores in Denmark.

Furthermore in regard to the structure of the fruit we have seen that the dehiscent utricle of *Sporobolus* is common to species from very diverse localities; that the long and triple-awned flowering glume which tightly encloses the caryopsis in *Aristida* is also common to species from plains, prairies, etc.; while other genera from these same places are destitute of such means for dispersing their seeds, *Glyceria*, *Distichlis*, *Schedonnardus*, etc.

Aristida fasciculata is, thus, associated with many and very diverse types of *Gramineae*, all of which would have been classified as "Xerophytes" unless the structure of other *Aristidae* had been considered at the same time in connection with their respective associates. It can hardly be denied that the similarity in structure, as exhibited by these plants, is too striking for separating them in such classes as Xerophytes, Halophytes or Mesophytes only on account of the conditions of the local surroundings, inasmuch as this same structure is illustrated by inhabitants of plains, fields, swamps, etc., with no modification of importance.

Very suggestive papers have been published in later years bearing upon such classification and defining the social occurrence of certain plant-species as constituting special societies. It may be that such exist, but we consider it a general mistake to establish such societies as xerophilous, hydrophilous, etc., without previously having studied their structural peculiarities. And the study of a single order or even a single, but large genus with wide distribution, may enable us to demonstrate such modifications as are probably the result of the influence of the environment, climate and soil. Furthermore by extending the research to a group of allies and associates a still more complete illustration may be obtained, than if we undertake to examine a large number of diverse types, representatives of orders, that are in no respect allied to each other, but which have that one peculiarity in common, that they are able to thrive in the same soil, in deserts, sand-dunes, bogs, woods, etc.

Our present knowledge of plant anatomy is too incomplete to enable us to distinguish between such structures as are

*) Warming, Eug., De psammophile Formationer i Danmark. (Vidensk. Medd. Naturhist. Forening 1891. p. 199.)

characteristic of bog-plants, of strand-plants, desert-plants, etc. This becomes the more evident when we compare the works, that have been published on this subject, where the author generally arrives at the conclusion that no clear distinction can be drawn between such and such society, as was at first considered as being perfectly natural and well defined. And it is now openly admitted that Halophytes and Xerophytes exhibit "prominent" or even "complete" agreements as to their structure, besides that one of the most prominent writers on this subject has lately expressed the opinion, that it is far from certain whether any characters really exist that may be defined as typical of Xerophytes or Halophytes*). Moreover this same author has pointed out the remarkable large number of Hydrophytes to which so-called xerophilous structures are common.

Comparing the structure of the *Gramineae*, which we have discussed in the preceding pages, it does not seem that *Aristida* from the plains of Colorado has characteristics warranting the designation of the species as a xerophyte in contrast to *A. spiciformis* and *palustris* from pine-barren ponds in Florida, which latter from their habitat would be called Hydrophytes. Similarly the species of *Sporobolus* are in no wise to be separated on structural grounds into Xerophytes or Halophytes. It seems, in other words, very unsafe to conclude that the inhabitants of deserts, bogs, etc., exhibit a corresponding structure which should be common to all plants from similar surroundings. On the other hand we may well speak of bog-plants, desert-plants, etc., these terms being only applicable as far as concerns the nature of the surroundings, but not including the internal structure. We have, therefore, made no attempt to classify the species of *Aristida*, described above, as Xerophytes or Halophytes, inasmuch as we have not examined more than about half of the species known of this genus.

We simply desired to call attention to the structural peculiarity exhibited by some of the species, which may prove of some advantage to a future classification of these, besides that the sketch of the leaf may furnish some illustration of the general structure of the *Gramineae* from the plains and prairies of North America.

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*) Warming, Eug., Halophyt-Studier. (Kgl. Danske Vidensk. Selsk. Skr. Vol. VIII. Series 6. p. 236. Kjöbenhavn 1897.)

Brookland, D. C., Febry., 1901.